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CLAIM OF PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

In support of the claim of priority under 35. U.S.C. § 119 asserted in the Declaration accompanying the above-entitled application, as filed, please find enclosed herewith certified copies of U.K. Application Nos. 0029850.5 and 0121197.8, filed in U.K. on 7 December 2000 and 31 August 2001, respectively, forming the basis for such claim.

Acknowledgment of the claim of priority and of the receipt of said certified copy(s) is requested.

Respectfully submitted,

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Attorneys for Applicants

By: ______________________
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Enclosure(s)

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2.	Patent application number *(The Patent Office will fill in this part)*	07 DEC 2000 **0029850.5**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Sony United Kingdom Limited The Heights Brooklands Weybridge KT13 0XW United Kingdom
	Patents ADP number *(if you know it)*	6522766001
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	Modifying Material
5.	Name of your agent *(if you have one)*	**D YOUNG & CO**
	"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	**21 NEW FETTER LANE LONDON EC4A 1DA**
	Patents ADP number *(if you know it)*	**59006**

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D YOUNG & CO | 7 Dec 2000

Agents for the Applicants

12. Name and daytime telephone number of person to contact in the United Kingdom | Richard Pratt | 023 80719500

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Modifying Material

The present invention relates to modifying material. Embodiments of the invention relate to watermarking material. Preferred embodiments of the invention relate to perceptible watermarking.

Material means one or more of video material, audio material and data material. Video is generic to still and moving images

It is known to watermark material. A watermark may be data embedded in material as a watermark. A watermark may be perceptible or hidden. Preferred embodiments of the present invention use perceptible watermarks.

It is also known to watermark an image by transforming the image from the spatial domain to a transform domain, e.g. to the wavelet domain and embed a watermark by changing the wavelet coefficients. The transform domain image with the watermark is then inverse transformed to the spatial domain. See for example "An image watermarking method based on the wavelet transform" by Hisashi Inoue, et al, IEEE, 0-7803-5467-2/99.

It is known to compression encode material especially images. If an image having a watermark is compression encoded, the watermark may be removed or damaged by the compression encoding. Also, if the watermark adds data to the image, then the compression is less efficient.

According to one aspect of the present invention, there is provided a method of modifying material represented by digital numbers in which the modification is introduced by modifying representations of the digital numbers during compression encoding of the material without increasing the number of bits used to represent the compressed material.

Most preferably, the modification is introduced by modifying representations of the digital numbers during compression encoding of the material without changing the number of bits used to represent the compressed material.

Preferably, the modification results in a watermark applied to the material. By combining the application of the modification and compression, the compression does not damage the modification. Also by not increasing the number of bits used, the bandwidth (data rate) of the compressed and watermarked material is not increased.

Most preferably, the modification is in accordance with an invertible algorithm.

By using an invertible algorithm, the modification is removable provided that the modified material is not processed or otherwise altered in a way that irreversibly alters the changed compression encoded data.

According to another aspect of the present invention, there is provided a method of watermarking and compressing material, the method comprising the steps of:

applying a transform to the material, the transformed material being material represented by digital transform coefficients which are digital numbers;

modifying representations of the said coefficients according to an invertible algorithm to apply the watermark without increasing the number of bits in the numbers; and

entropy encoding the modified numbers to effect compression of the material.

The modification is such that the number of bits used to represent the compressed modified material is not increased relative to the number of bits which would be used to represent the compressed unmodified material. Most preferably the number of bits is not changed relative to the number of bits which would be used to represent the compressed unmodified material.

The invention also provides a computer program product arranged to implement the method of the said one or another aspect when run on a computer.

The invention also provides apparatus for carrying out the method of said one or another aspect.

For a better understanding of the present invention, reference will now be made by way of example to the accompanying drawings in which:

Figure 1 is a schematic block diagram of a video signal processor embodying the invention;

Figure 2 explains how an image is changed by the processing of the system of Figure 1;

Figures 3A and 3B schematically illustrate the contents of frame stores of the system of Figure 1;

Figure 4 is a flow chart illustrating the processing of DC transform coefficients;

Figure 5 illustrates the encoding of DC coefficient values;

Figures 6, 7, 8 and 9 are flow charts illustrating the processing of AC transform coefficients;

Figure 10 is a schematic diagram of a smart card;

Figure 11 is a schematic block diagram of a decoder embodying the invention; and

Figure 12 is an example of a watermarked image produced in accordance with the invention.

Overview

The embodiments of the invention described herein watermark an image. Figure 12 is an example of a watermarked image produced by an embodiment of the invention.

Encoder, Figure 1.

Figure 1 is an example of an encoder. The encoder of Figure 1 is for example a high definition camera/recorder which includes an image compression system. The encoder comprises a source 1 of a color analogue image and an analogue to digital converter and processor 2 which samples the image according to the well known 4:2:2 format. As shown in Figure 2, a frame of the luminance component image has 1920 samples in each of 1080 lines. The processor 2 filters the image and outputs a 3:1:1 subsampled image. The luminance (Y) component has 1440 digital samples on each of 1080 lines as shown in Figure 2b. A demultiplexer 3 separates odd and even samples onto separate odd and even channels. Thus as shown in Figure 2c, a frame of even Y samples has 720 samples on each of 1080 lines. A frame of odd samples is the same.

In this example, the encoder is part of a camera/recorder. The odd and even samples are shuffled according to a known shuffling algorithm in processors 4o and 4e. The odd and even samples are recorded on separate tracks of a video tape in known manner. Shuffling is performed to minimise the effect of tape defects on an image reproduced from the tape, as is well known in the art. Shuffling is also used to improve shuttle playback. Shuffling is not essential to the invention.

Each frame of odd and even shuffled digital samples, represents a spatial domain image. The odd and even frames are transformed to the DCT domain by respective transformers 5o and 5e. As shown in Figure 2d, each transformed frame of odd (or even) Y samples comprises 90 by 135 DCT blocks, each block comprising 8 by 8 DCT coefficients as shown in Figure 2e. Each DCT block has one DC coefficient denoted DC in Figure 2e and 63 AC coefficients, one example of which is denoted by AC in figure 2e.

The DCT coefficients are quantised in quantisers 6o and 6e, the quantisation being controlled by a control value Q in known manner. In the absence of watermarking, the odd and even frames of quantised DCT coefficients are entropy

encoded in entropy encoders 8o and 8e in known manner. The entropy encoding in this example includes encoding using Huffman encoding. The entropy encoded quantised coefficients are in this example recorded in known manner on a tape: that is not shown in Figure 1. Recording could be on other recording media, for example discs.

Modifying the quantised DCT Coefficients to apply the watermark.

The odd and even channels of the encoder have change processors 7o and 7e which modify the quantised luminance (Y) DCT coefficients to apply the watermark. The following description refers to only one, 7, of the processors. The other processor operates in the same way. The following assumes by way of example that the quantised DCT coefficients are represented by n bit numbers where n is in the range 8 to 14; that is DC coefficients may have 8 to 14 bits; and AC coefficients have 14 bits. For ease of description the following refers to n bit numbers.

Defining the form of the watermark.

Referring to Figure 3A and to Figure 12, the form of the watermark is defined by a bit map stored in a frame store 9a of the change processor 7. The bit map contains data selecting the DCT blocks in which coefficients are to be changed to apply the watermark. For example a bit value 0 in a location on the store 9A indicates the a DCT block in a corresponding location in the image is not to be changed whereas bit value 1 selects the block for change.

In a preferred embodiment there are two such stores. One selects DCT blocks in which AC coefficients are to be changed and the other selects blocks in which the DC coefficient is to be changed. Most preferably the selections made by the two stores are independent. The stores 9 are referred to hereinafter as template stores. The following description assumes that DC coefficients are processed differently to AC coefficients. In an alternative embodiment only DC coefficients are changed to apply a watermark. In a further embodiment only AC coefficients are changed to apply a watermark

Processing DC coefficients, Figures 4 and 5.

Referring to Figure 3B, the change processor 7 has a change function store 9B which stores a change value C for the DC coefficient of each DCT block selected by the bit map in the DC template store 9A.

Referring to Figure 4, the change value C is calculated by the processor 7 in the following way.

S1. The DC template of Figure 3A is created. Different levels L may be specified for different parts of the watermark as illustrated in Figure 3A. L is defined by a 8 bit number and so it has values in the range 0 to 255. In Figure 3A L has values 5 and 127 by way of example. The levels may be stored in the DC template.

S2. Pseudo random numbers RN1 are generated based on a first key, Key1. The numbers RN1 are constrained within a predetermined range min<=RN1<=max for example 100<=RN1<=1000. A new random number is generated for each DCT block which is to have its DC value changed (as indicated by the DC template).

S3. The change values C are calculated according to

$$C=(L/M).\ RN1$$

where M is the maximum value which L can take: in this example M=255. The change values are stored in the change store 9B.

It will be recalled that the same process occurs in both the even sample change processor 7e and the odd one 7o. However, the quantisation scales applied to the odd and even channels may be different. Thus different changes could be applied to even and odd samples. That would produce a striped image. To prevent that, step S4 is implemented.

Steps S1 to S3 may take place before an image is compressed and watermarked. The adjustment of the change values C by step S4 takes place during processing because it depends on the particular quantisation scales applied to the odd and even samples during processing.

S4. The digital change value C is adjusted as follows to produce an adjusted value C^ where

C^ = C>>(13 – B), where B is the number of bits needed to specify the DC value after quantisation, and >> means right shift(by (13-B) bits). That occurs in both the odd and even channels and results in approximately the same change being applied in both channels. There may be different values for B on the odd and even tracks Bo and Be.

S5. The quantised DC coefficients are then adjusted by the values C^ according to an invertible algorithm. The quantised DC coefficients each have n bits, where n may differ from DC coefficient to DC coefficient. The change is such that for any coefficient the number n of bits does not change.

Figure 5 illustrates a currently preferred algorithm for changing the DC coefficient values. Assume by way of example that C^=10 and n =8 bits so the coefficient has a value in the range –128 to + 127. Starting at –128, the bottom of the range, the range of values is divided into sections each of range 2x10. Sections –128 to –109; -108 to -89; and so on to +111 are shown. The whole range does not divide into an integer number of sections each of range 2x10. Thus there is a top section of +112 to +127.

The algorithm operates by swapping a value in the top half of a section with for a values in the bottom half. Thus values –128 to –119 swap with values –118 to –109. Thus if a coefficient has an original value –118 ,before adjustment by C^=10, it is replaced by –128 after adjustment by C^. As another example if an original value is –107, it becomes –97 after adjustment. In the top section +112 to + 127 the same process occurs but the half sections are +112 to +119 and +120 to + 127 and the swapping is as shown in the Figure.

The example given divides the whole range into section beginning at the bottom (-128) of the range. The division may take place starting at the top (+127) of the range. In a preferred embodiment, the division begins at the top or bottom according to the value of a pseudo randomly generated bit PRB generated based on a key, Key2. PRB may pseudo randomly change for every DC coefficient. The values of the bit PRB are preferably stored in the change store together with C.

When a DC coefficient is produced by the quantiser Q, the processor 7 determines from the change store the value of C applicable to the coefficient and the value of PRB. The processor 7 adjusts the value of C to C^. The value of that coefficient is adjusted according to C^ and the algorithm. Using the example of Figure 5, if the coefficient has an original value of –96 it is replaced by –106.

In summary, the n bit numbers representing the coefficients are members of a set and a said number is modified by transposing it with another member of the set chosen according to the invertible algorithm. As shown in Figure 5, if a number N1 is

to be changed by an amount X it is transposed with another member N2 of the set where |N1-N2| = X, except at one end of the range where only a change of less than X is possible.

It will be appreciated from the foregoing that the number of bits is not changed.

S17, S18. The foregoing description may apply to a single frame of a still image. For video with many frames in a clip, the change values C^ and PRB stored in the store 9B are applied to all the frames in the clip. However in addition, to increase security, a small pseudo random variation RN2 based on a key Key5 is added to the change values C of each frame. The small variation is chosen so that the number of bits does not increase. At step S3, the change store is established and remains fixed for the clip. The small variation is a small pseudo random nuber e.g. $-50 <= RN2 <= 50$, and it is added to C just prior to step S4. Each C gets a new value of RN2. The PRBS generating RN2 is *not* reset every frame , so different frames have different sequences of RN2.

Processing AC coefficients, Figures 6 to 8.

S6. An AC template is created. The bit map in the AC template selects the DCT blocks in which AC coefficients are to be changed.

S61. The value of each AC coefficient is tested; if it equals zero, no change is made to its value; otherwise it is changed.

S7, S8 and S9. The AC coefficients in the selected blocks are compared with a threshold Ts. If the magnitude of a coefficient is below Ts then its sign may be changed. If the value is greater than Ts the sign must not change. Although it is not essential to the principle of the invention to prevent a sign change in an AC coefficient, it has been found that a sign change for large valued coefficients creates a watermark which is unpleasant.

S10. The numbers representing the AC coefficients are changed according to an invertible algorithm and a key, Key3.

Figure 7 illustrates one example of the invertible algorithm. The algorithm operates on quantised AC coefficients prior to entropy encoding.

Referring to table 1, which is attached to the end of this description, the coefficient values are represented by a variable length code VLC and a fixed length

code FLC. The VLC specifies which of the groups an AC coefficient lies in. The FLC is an index which indicates which value in the group is equal to the AC coefficient

Step S11 determines which group the coefficient lies in.

Step S111 determines the index of the coefficient in the group.

In step S12 the fixed length code of AC coefficients in blocks selected by the AC template is changed by adding to it a pseudo random number RN3 based on a key, Key3. To ensure that the number of bits does not change the sum "wraps round". For example if the fixed length code is 110 and the PRN is 010 then the sum wraps round to 000 rather than 1000. If no change of sign is to occuras indicated by steps S7 and S9, then the wrap around is performed so as to preserve the sign of the ~~fixed length code~~ coefficient.

In Step S121 the coefficient value is set to the value pointed to by the new index.

Figure 8 illustrates another example of the invertible algorithm. The algorithm operates in the same way as Figure 7 except step S12 is replaced by step S13.

In step S13 the fixed length code is encrypted according to an invertible encryption code and a key Key3'. The number of bits is not changed.

Figures 7 and 8 are concerned with changing the value of a coefficient to another value in the same magnitude group.

Figure 9 illustrates an invertible algorithm for changing the order of coefficients . This may be used in addition to the algorithm of Figure 7 or 8.

S14. The number of bits to entropy encode a sequence of AC coefficients is determined.

S15. The change processor 7 attempts to find a permutation of the order of coefficients which does not change the number of bits produced by entropy encoding.

S16. If a permutation is found, then a decision is made to either change the order or not change the order. The decision depends on the value of a pseudo random number PRB2 defined by a key Key4.

In a modification of the process, the AC coefficeints in a block are selected for change. In such a block not all coefficients are changed. The selection may be a preset fixed selection or a selection which varies. The selection may be pseudo random based on a key.

Creating watermarked spatial domain images.

The compressed watermarked image may be stored in compressed form on the tape. To view the image it must be decompressed.

Referring to Figure 11,the Figure shows only the "odd " channel of the decoder. The "even " channel is similar. The compressed image is entropy decoded (18), dequantised (16) and inverse transformed (15). The resulting spatial domain samples are unshuffled (14) and the odd and even samples remultiplexed (13) to produce a watermarked spatial domain image. The remultiplexed samples are inverse filtered to produce a 4:2:2 image. Figure 12 is an example of such an image.

It will be noted that a watermark removal processor 17 of Figure 11 is bypassed by bypass 19 for the purpose of viewing the watermarked image.

Removing the Watermark.

Data Carrier, Figure 10

In order to remove the watermark, the decoder must have the following removal data:

The AC and DC templates, levels L, the maximum and minimum values for RN1, the keys 1,2, 3 4 and 5 for generating the pseudo random numbers and bits, the algorithms and the threshold Ts. The keys are generated in the encoder and are not predetermined.

In the currently preferred embodiment, the removal data is stored in a data carrier preferably securely. Most preferably the carrier is a smart card SC. The encoder has an interface via which the change processors 7e and 7o download the removal data into the smart card SC.

The removal processors 17 of the decoder have a similar interface for receiving the removal data from the smart card SC.

Removal of changes from the DC coefficients

Referring to Figures 4 and 11, the removal processor 17 downloads the DC template, Key1 and the limits to the range of RN1 from the smart card SC.

S1. The template and levels L are available from the smart card.

S2. The removal processor 17 recreates from the Key1 and the limits the pseudo random numbers RN1.

S3. The changes C are recalculated from the template, L and RN1.

S4. The adjusted change values C^ are calculated and stored in a change store as shown in Figure 3B together with the pseudo random bits PRB1 regenerated from Key2.

S5. The DC coefficients are restored to their original values by inverting the algorithm with reference to PRB1.

S17, S18. For video clips, RN2 is regenerated from Key5 and subtracted from C.

Restoring AC coefficients

Referring to Figure 6:

S6. The AC template is downloaded from the smart card.

S61. The coefficients are tested to determine whether or not they have a value of zero. If the value is non zero then they were subject to change at the encoder and thus also at the decoder.

S7 to S9. The coefficient values are compared with Ts downloaded from the smart card. That allows the processor to determine which coefficients have a sign change.

S10. The AC coefficients are restored to their original values by inverting the algorithm with reference to Key 3.

Referring to Figures 7 and 8, steps S11 and S111 are followed as in the process of changing the coefficients.

Referring to Figure 7, at S12 RN3 is regenerated from Key3and is subtracted from the index.

Referring to Figure 8, at S13, the encryption is reversed using Key3'.

Referring to Figure 9;-

S14. The number of bits to entropy encode a sequence is determined.

S15. The change processor 7 attempts to find a permutation of the order of coefficients which does not change the number of bits required to be entropy encoded.

S16. If such a permutation is found, then it is possible that in the change process a decision was made to change the order.. The decision depends on the value of the pseudo random number PRB2 defined by Key4.

PRB2 indicates whether the sequence has been changed. If it has, the change is inverted.

Security

The algorithms used to apply the watermark may be common to many different users. Security is provided by:

a) the keys Key1,2,3 4 and 5which are chosen and generated by the users;

b) the levels L which are chosen by the users; and

c) the limits on RN1 which are chosen by the users.

The sign change threshold may provide some security because it is selectable by the users.

The DC and AC templates are not if a visible watermark is applied to an image because the template is a least partially visible in the image.

Smart cards are physically and logically designed to store data securely.

Related system and method

The method and apparatus described herein may be used with the method and system disclosed in copending application 00 , attorney file P/10406, I-00-153 the disclosure of which is incorporated herein by reference.

Table 1.

VLC Group	Number of FLC Bits	Description
0	0	EOB code
1	1	(1)*0, +/- 1
2	2	(2 to 3)*0, +/- 1
3	3	(4 to 7)*0, +/- 1
4	4	(8 to 15)*0, +/- 1
5	5	(16 to 31)*0, +/- 1
6	6	(32 to 63)*0, +/- 1
7	0	(1)*0
8	1	(2 to 3)*0
9	2	(4 to 7)*0
10	3	(8 to 15)*0
11	4	(16 to 31)*0
12	5	(32 to 63)*0
13	1	+/- 1
14	2	-3 to −2, +2 to +3
15	3	-7 to −4, +4 to +7
16	4	-15 to −8, +8 to +15
17	5	-31 to −16, +16 to +31
18	6	-63 to −32, +32 to +63
19	7	-127 to −64, +64 to +127
20	8	-255 to −128, +128 to +255
21	14	-8192 to −256, +256 to +8191

In this table:

1. (x to y)*0, +/- 1 means from "x" to "y" zero value coefficients followed by a coefficient of +1 or -1
2. (x to y)*0 means from "x" to "y" zero value coefficients.

CLAIMS

1. A method of modifying material represented by digital numbers in which a modification is introduced by modifying representations of the digital numbers during compression encoding of the material without increasing the number of bits used to represent the compressed modified material.

2. A method according to claim 1, wherein the modification is introduced by modifying representations of the digital numbers during compression encoding of the material without changing the number of bits used to represent the compressed modified material.

3. A method according to claim 1 or 2, wherein the representations are modified during compression encoding without increasing the number of bits in the representations.

4. A method according to claim 1 2 or 3, wherein the said modification is in accordance with an invertible algorithm.

5. A method according to claim 1, 2, 3 or 4, comprising the step of selecting the numbers to be modified.

6. A method according to any preceding claim, wherein the modification is perceptible.

7. A method of watermarking and compressing material, the method comprising the steps of:

applying a transform to the material, the transformed material being material represented by digital transform coefficients which are digital numbers;

modifying representations of the said coefficients according to an invertible algorithm to apply the watermark without changing the number of bits in the numbers; and

entropy encoding the modified numbers to effect compression of the material

8. A method according to claim 7, wherein the further step modifies the representations of the transform coefficients and the entropy encoding step entropy encodes the modified representations.

9. A method according to claim 7 or 8, comprising the step of selecting the coefficients to be modified.

10. A method according to claim 7, 8 or 9, wherein the values of numbers representing the coefficients are changed pseudo randomly according to the invertible algorithm to modify them.

11. A method according to claim 7 8 or 9, wherein the invertible algorithm is an encryption algorithm and numbers representing the coefficients are encrypted according to the invertible algorithm to modify them.

12. A method according to claim 7, 8 or 9, wherein the representations of the coefficients are members of a set and a number representing the representation is modified by transposing it with another member of the set chosen according to the invertible algorithm.

13. A method according to claim 12, wherein if a number N1 is to be changed by an amount X it is transposed with another member N2 of the set where $|N1-N2| = X$

14. A method according to any one of claims 7 to 13 , wherein the said transform coefficients are DCT coefficients.

15. A method according to claim 14 when directly or indirectly dependent on claim 9 , wherein the coefficients are grouped in blocks, the selecting step comprising selecting blocks of coefficients the representations of which are to be changed.

16. A method according to claim 15, wherein the blocks each comprise DC and AC coefficients.

17. A method according to claim 16, wherein the selecting step selects AC coefficients for change in some blocks and DC coefficients for change in other blocks.

18. A method according to claim 17, wherein DC coefficients are modified differently to AC coefficients.

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19. A computer program product arranged to carry out the method of any one of claims 1 to 18 when run on a computer.

20. Apparatus arranged to carry out the method of any one of the preceding claims.

21. Apparatus for modifying material represented by digital numbers in which the modification is introduced by modifying representations during compression encoding of the material without increasing the number of bits used to represent the compressed modified material.

22. Apparatus according to claim 21, wherein the representations are modified during compression encoding without increasing the number of bits in the numbers.

23. Apparatus according to claim 21 or 22, wherein the said modification is in accordance with an invertible algorithm.

24. Apparatus according to claim 21, 22, or 23, comprising the step of selecting the numbers to be modified.

25. Apparatus according to any one of claims 21 to 24, wherein the modification is perceptible.

26. Apparatus for watermarking and compressing material, comprising:

a transformer for applying a transform to the material, the transformed material being material represented by transform coefficients represented by digital numbers; and

an entropy encoder for entropy encoding the numbers to effect compression of the material; and

a processor arranged to modify representations of the said numbers according to an invertible algorithm to apply the watermark without changing the number of bits in the said numbers.

27. Apparatus according to claim 26, wherein the said processor modifies the entropy encoded numbers.

28. Apparatus according to claim 26, wherein the said processor modifies the transform coefficients and the entropy encoder entropy encodes the modified numbers.

29. Apparatus according to claim 26, 27 or 28, wherein the said processor selects the coefficients to be modified.

30. A method substantially as herein before described with reference to the accompanying drawings.

31. Apparatus substantially as herein before described with reference to the accompanying drawings.

32. A data carrier storing a template defining locations in material which are to be modified, and other data required to apply the modification(s).

33 A data carrier storing a template defining locations in material which are to be modified, and other data required to remove the modification(s).

34. A carrier according to claim 32 or 33, wherein the said other data includes at least one security keys for generating a pseudo random number.

35. A carrier according to claim 34, wherein the said other data includes at least data relating to limits on the value of the pseudo random number.

36. A carrier according to claim 32, 33, 34 or 35, wherein the said other data includes data relating to the magnitude of the modification(s).

37. A camera/recorder including apparatus according to any one of claims 20 to 29 and 31.

38. A method of removing a modification applied to material by the method of any one of claims 1 to 18.

ABSTRACT

WATERMARKING MATERIAL

Material is represented by transform coefficients represented by digital numbers. A method of perceptibly watermarking the material comprises the steps of: changing representations of the said numbers according to an invertible algorithm without changing the number of bits in the said numbers; and encoding the changed n bit numbers to effect compression encoding of the material.

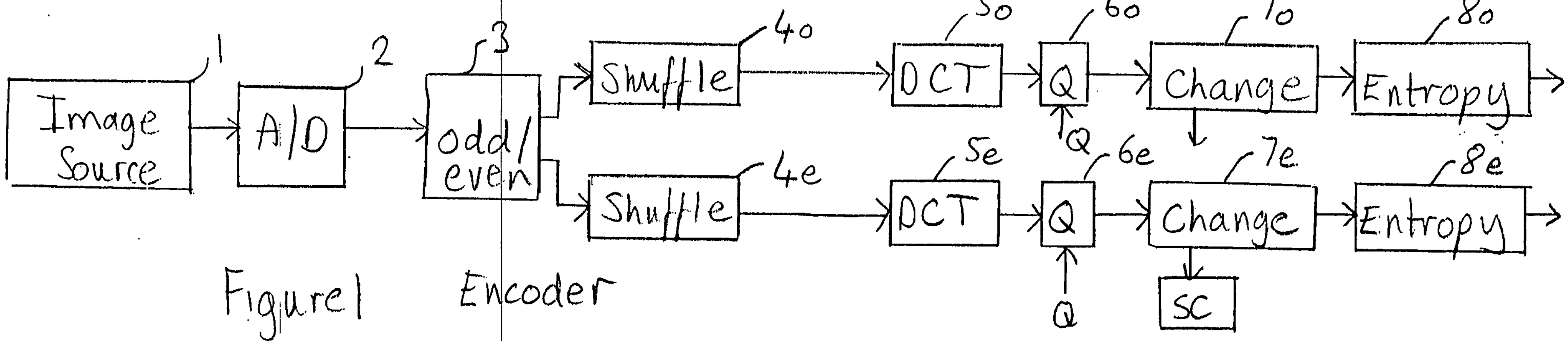


Figure 1 Encoder

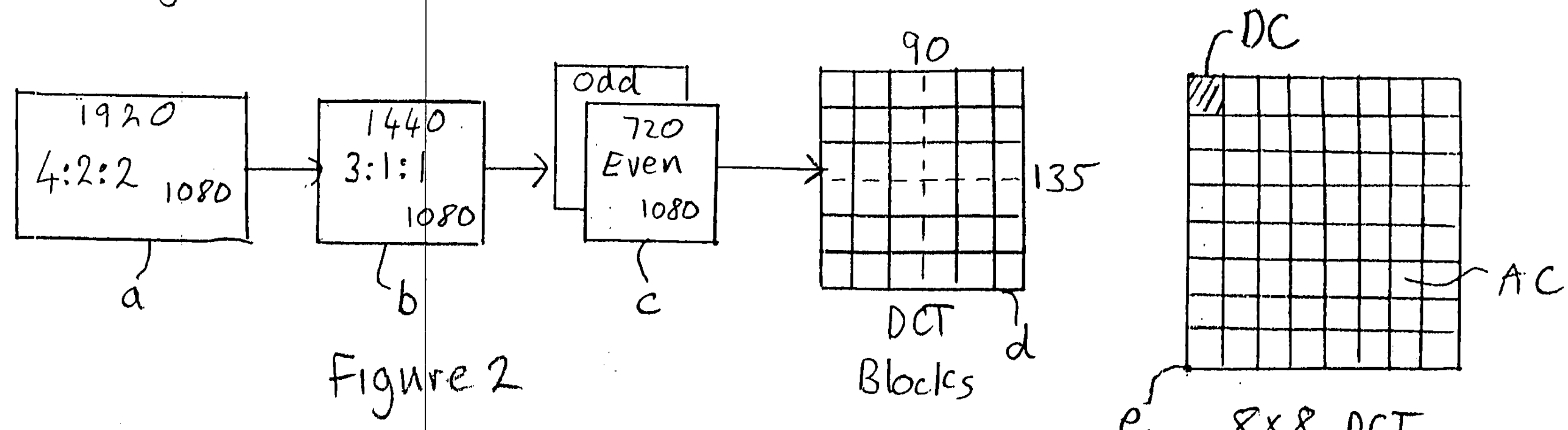
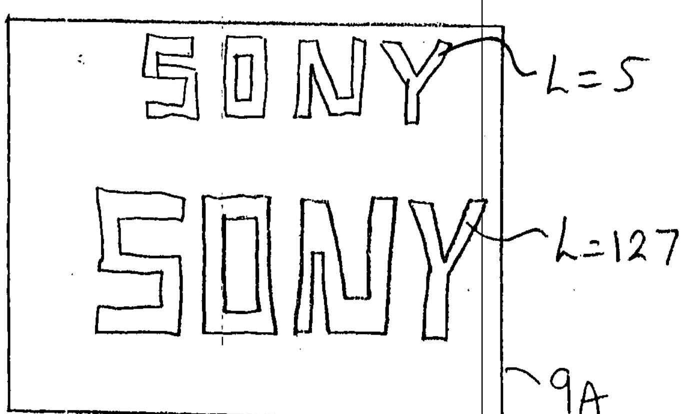
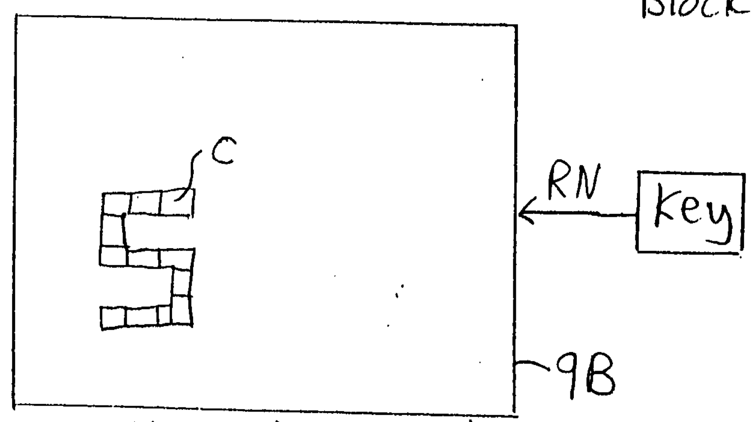


Figure 2



Template Store
Figure 3A



Change Function Store
Figure 3B

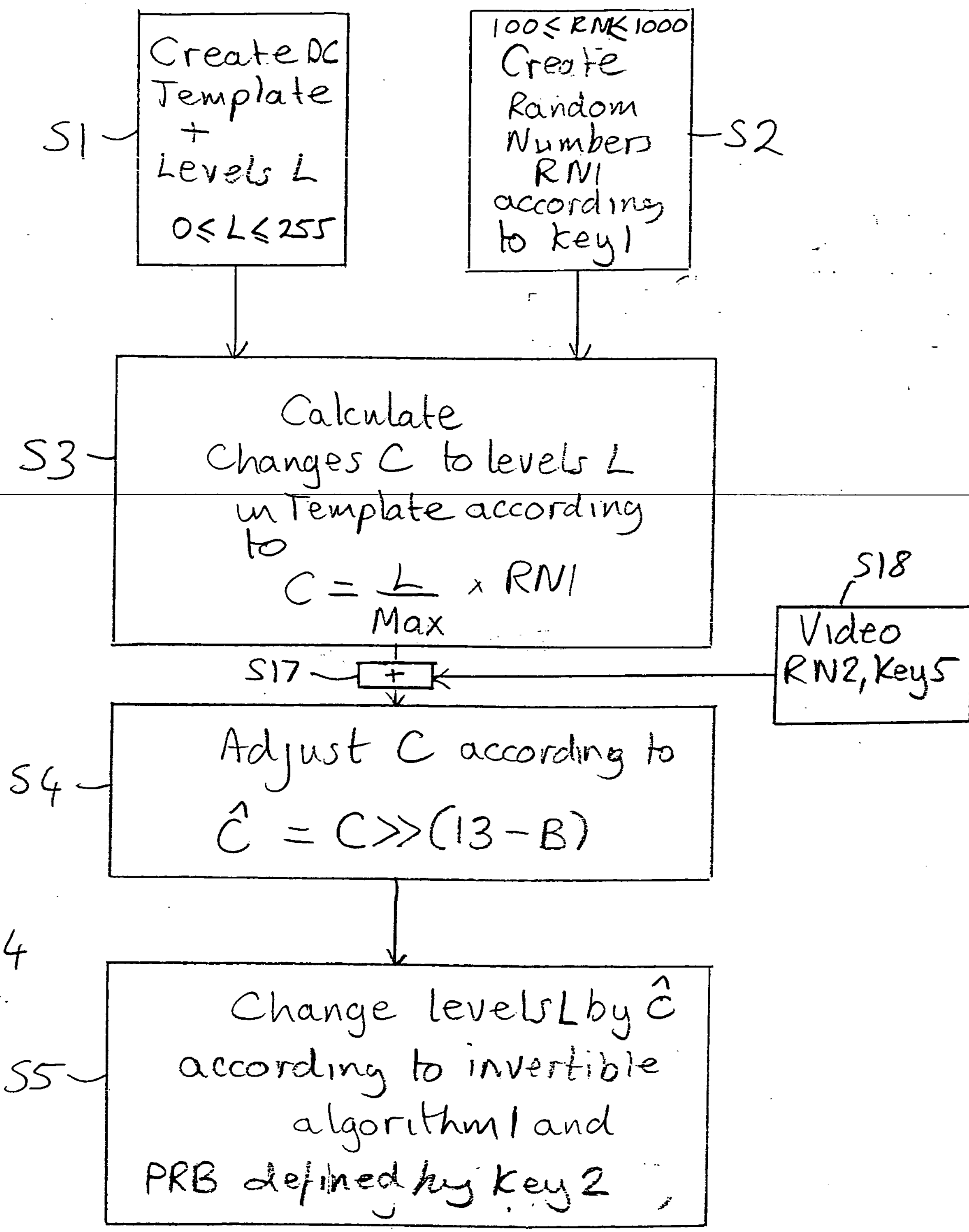


Figure 4

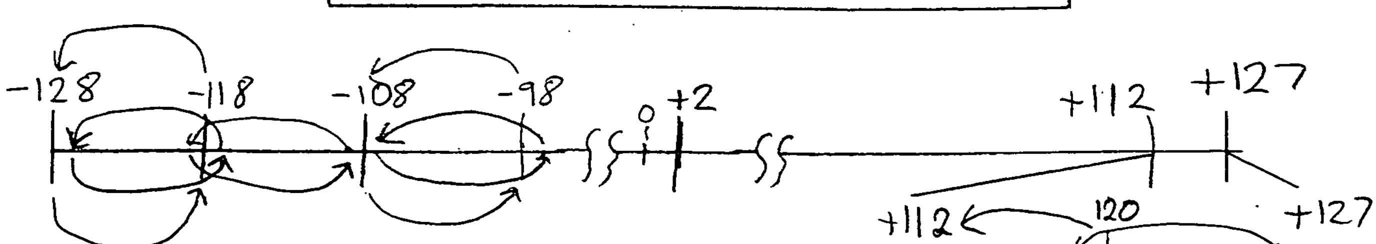


Figure 5

I-00-147

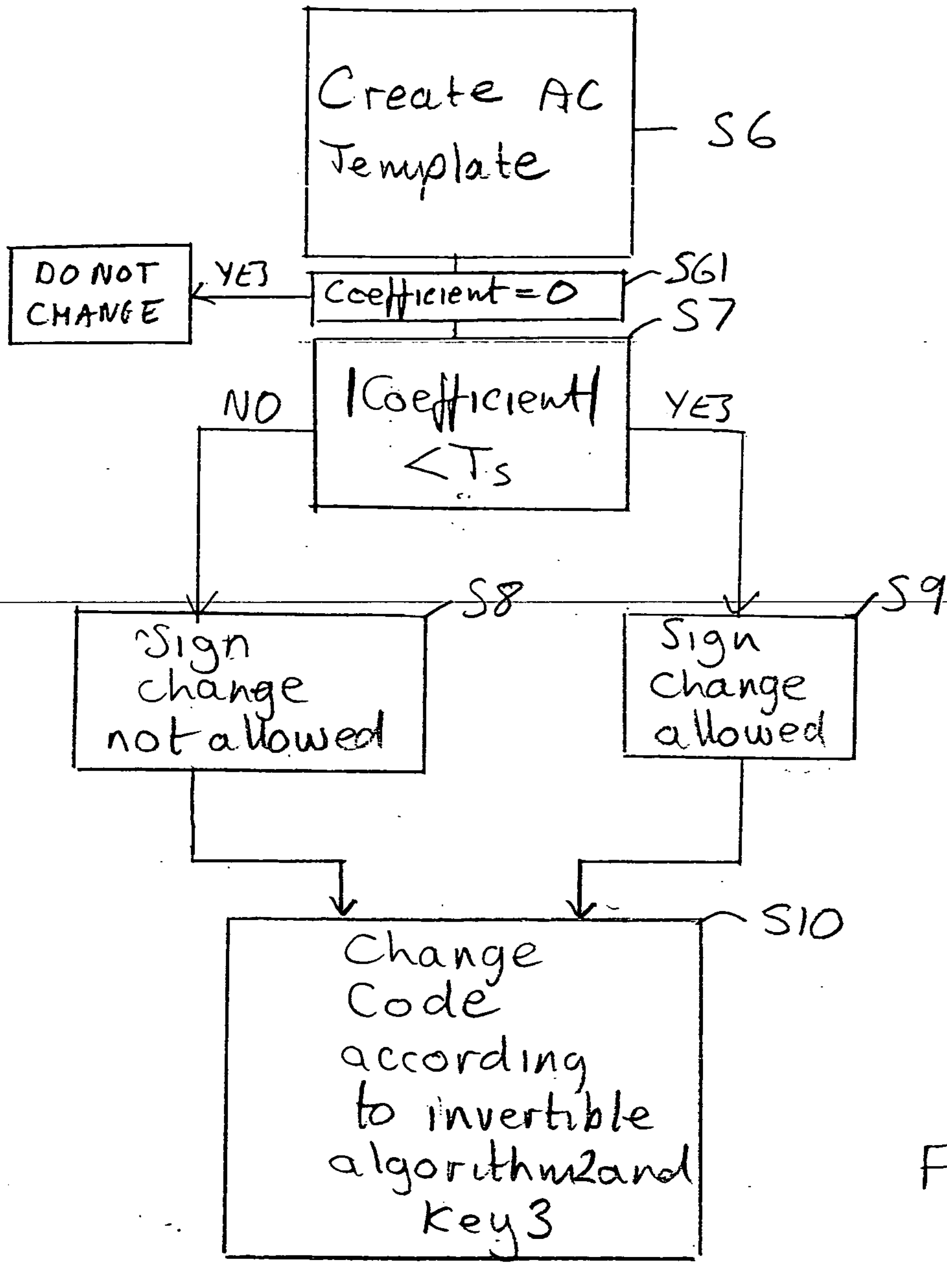

Create AC Template
S6
DO NOT CHANGE
YES
Coefficient = 0
S61
S7
NO
|Coefficient| < Ts
YES
S8
S9
Sign change not allowed
Sign Change allowed
S10
Change Code according to invertible algorithm2 and Key3

Figure 6

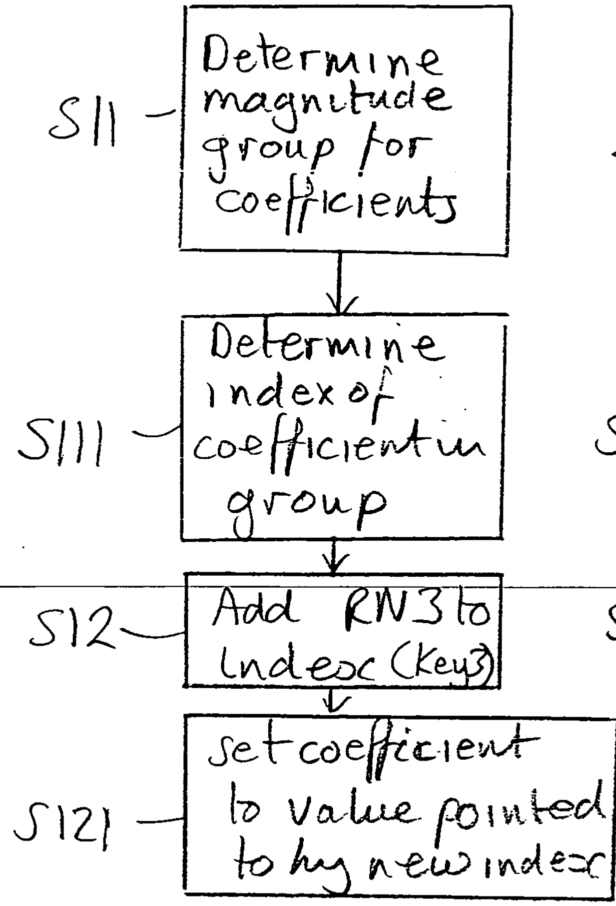


Figure 7

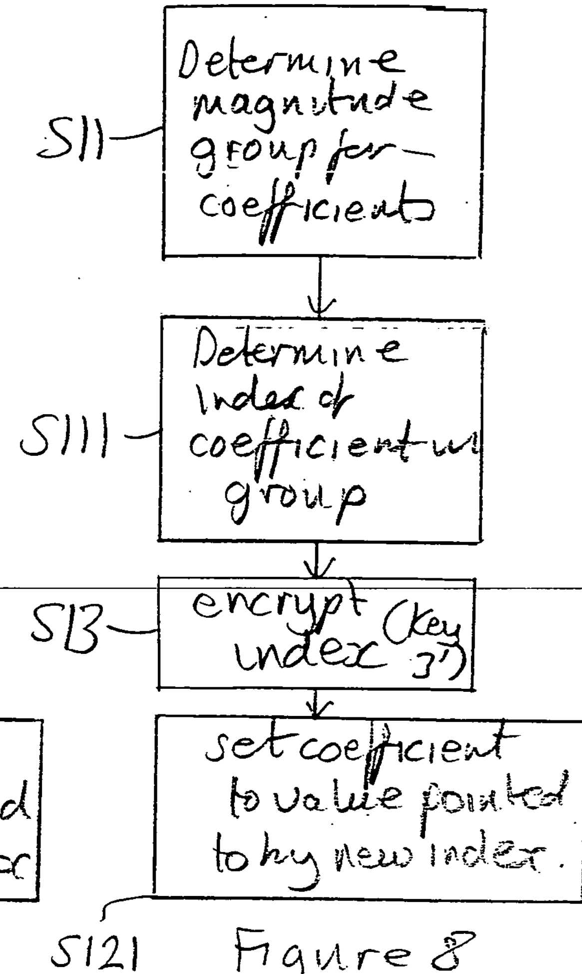
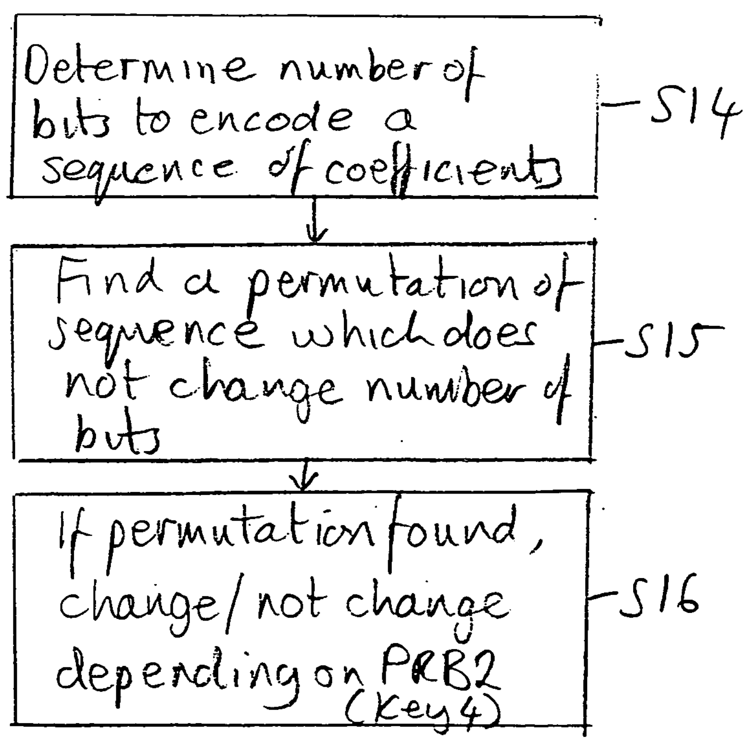


Figure 8

Figure 9



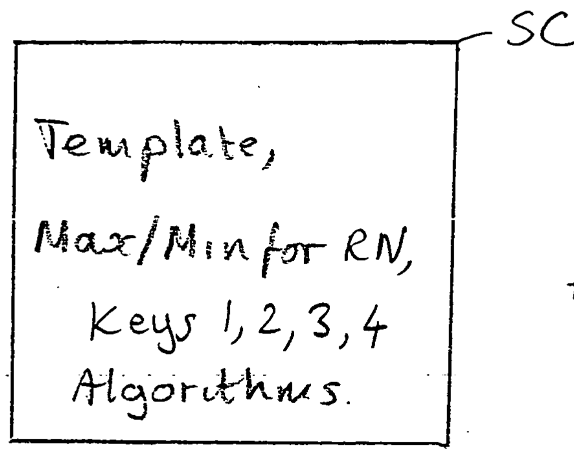
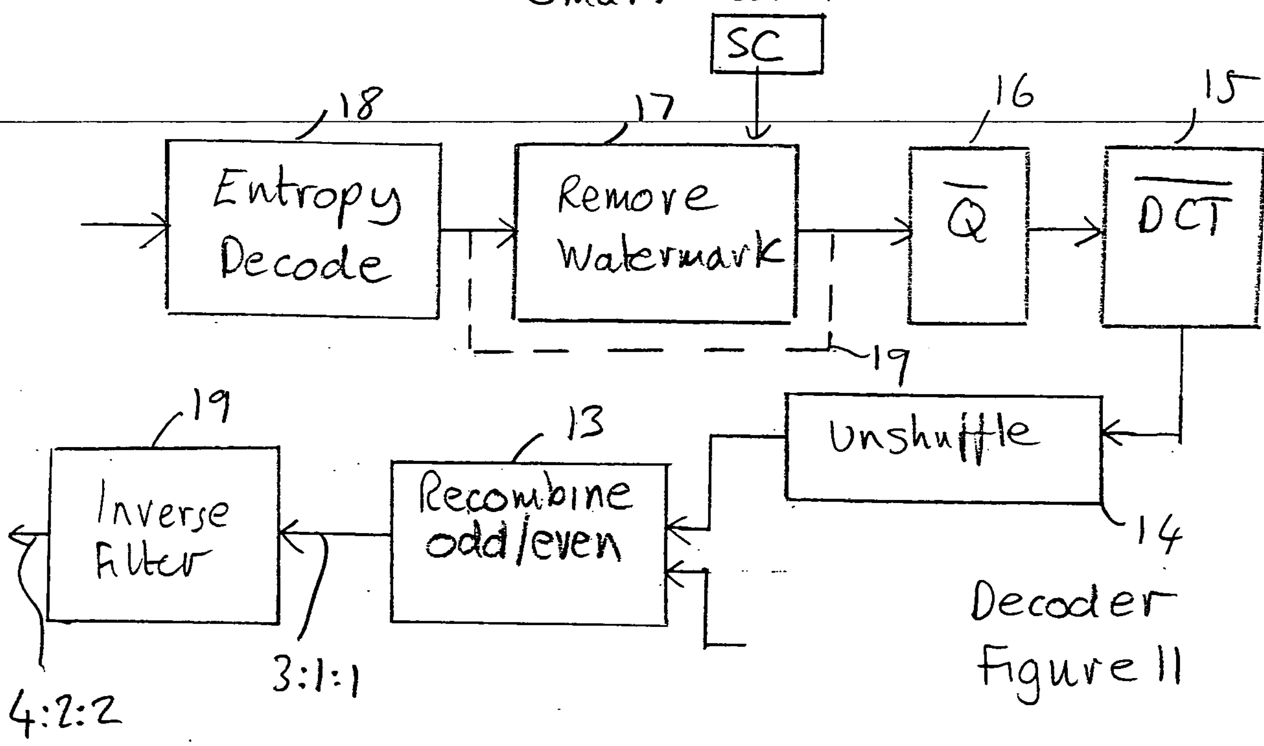
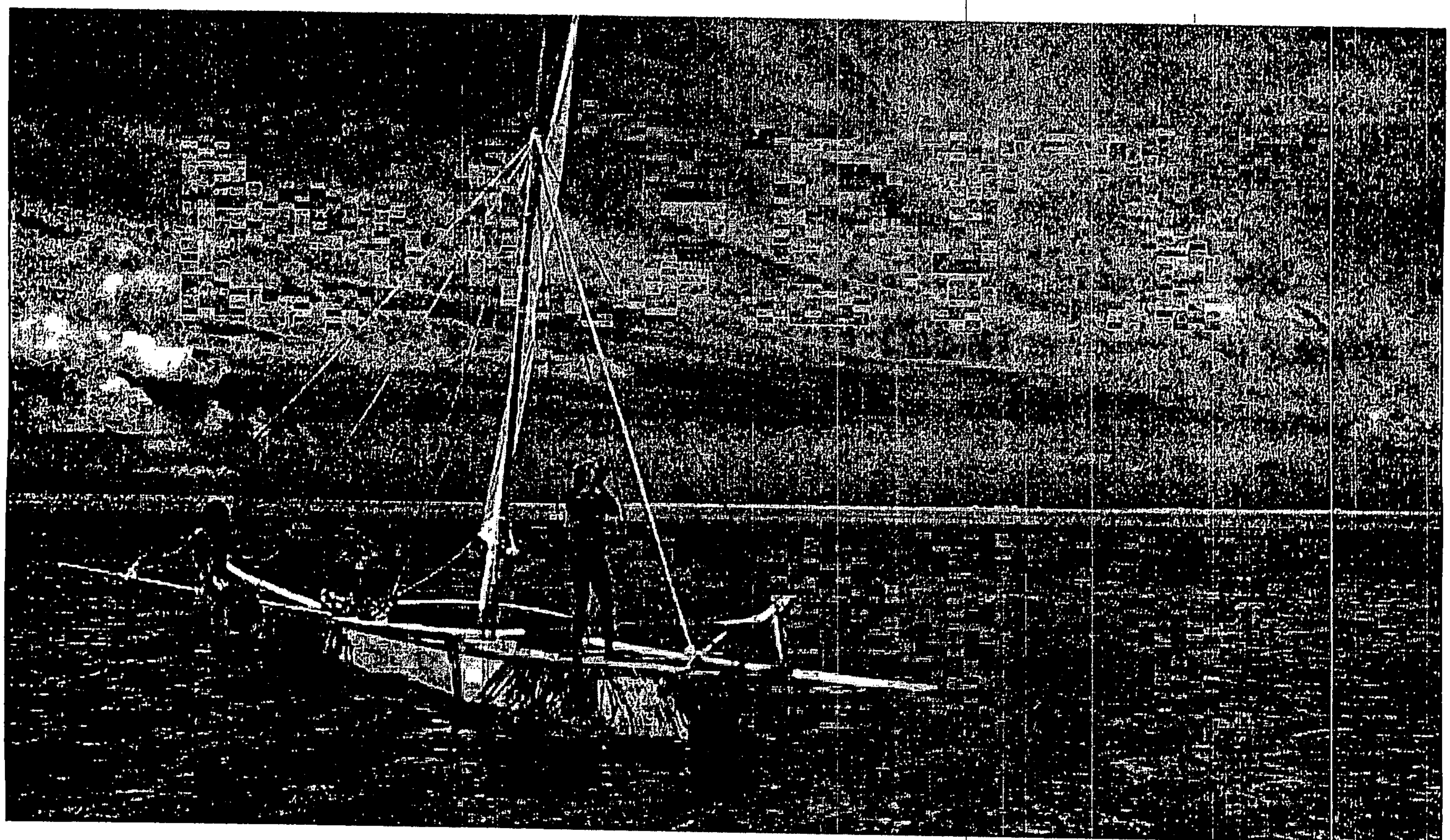


figure10



Decoder
Figure 11



Example Watermarked Image

Figure 12